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NAVAL AIR WARFARE CENTER AIRCRAFT DIVISION
PATUXENT RIVER, MARYLAND

TECHNICAL REPORT

REPORT NO: NAWCADPAX/TR-2008/104

TRIVALENT CHROMIUM PROCESS (TCP) AS A SEALER FOR MIL-A-8625F TYPE II, IIB, AND IC ANODIC COATINGS

by

Craig Matzdorf
Erin Beck
Amy Hilgeman
Ruben Prado

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The performance of TCP as a sealer was compared to standard sealers like dichromate and water which are commonly used in aerospace and other industries. Paint adhesion was performed with commonly used high-solids and water-borne chromated and chromate-free primers qualified to MIL-PRF-23377 and MIL-PRF-85582.

In these series of evaluations, TCP performs as good as or better than chromate in corrosion resistance and equal to chromate in paint adhesion. TCP is far superior to water for sealing. An additional benefit is that the TCP is applied at ambient conditions for 5 to 10 min. Chromate and water sealers are applied at 190°F to 200°F for up to 25 min.

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In these series of evaluations, TCP performs as good as or better than chromate in corrosion resistance and equal to chromate in paint adhesion. TCP is far superior to water for sealing. An additional benefit is that the TCP is applied at ambient conditions for 5 to 10 min. Chromate and water sealers are applied at 190°F to 200°F for up to 25 min.

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ADMINISTRATIVE INFORMATION

The work described in this report was performed by the Materials Division (4.3.4) at NAWCAD Patuxent River, Maryland, and FRC Southeast, Jacksonville, Florida. The work was funded by the NAVAIR Aviation Pollution Prevention Program. Tasks were completed under the supervision of Mr. Craig A. Matzdorf, Ms. Kate Laubernds, Ms. Erin Beck, Ms. Amy Hilgeman, and Mr. Ruben Prado.

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INTRODUCTION

The sealing of anodized aluminum is a mature technology with no real improvements to the process or performance of sealed coatings in at least 20 years. Most recent research and development focused on reducing the amount of hexavalent chromium in chromate-based hot sealing processes from 5% to 1,000 ppm. These reduced chromate sealers are referred to as "dilute chromate" and now used regularly at aerospace manufacturers and Department of Defense repair facilities.

Chromate-based sealers are considered the best when maximum corrosion resistance is desired for anodized aluminum. Water-based sealers are attractive when reduced corrosion performance is acceptable. Both of these processes require operating temperatures of 190°F to 200°F and immersion times of up to 25 min to achieve proper coating formation and corrosion resistance.

Each of these processes has drawbacks. The chromate-based process uses hexavalent chromium which is toxic and a carcinogen. With the recent reduction of the Occupational Safety and Health Administration hexavalent chromium permissible exposure limit and world-wide pressure to eliminate the use of hexavalent chromium, many suppliers and users are pursuing alternative processes which are technically equivalent without the environmental, safety, and health risks. The chromate-based process is run at a high temperature for a relatively long time. Processes with reduced operating temperatures and immersion times are attractive as cost reduction targets.

Hot water sealing does not have the environmental, safety, and health risk associated with chromate-based sealers, but it is sensitive to impurities and difficult to maintain as a process. Anodize coatings with a hot water seal are also inferior in corrosion resistance compared to a chromate-based seal. Finally, the hot water process has the same temperature and time costs as chromate-based processes.

In an effort to find a solution to these drawbacks, trivalent chromium compositions were investigated for their ability to seal anodized aluminum from a variety of processes identified in MIL-A-8625.

BACKGROUND

Trivalent chromium compositions and processes were originally developed as a chromate conversion coating alternative for aluminum alloys (AAs) (references 1, 2, and 3). During the research and development for this application, researchers noticed that AAs which had not been deoxidized would still react with the trivalent chromium composition and form coatings with corrosion resistance properties that were better than having no coating but not as good as coatings that were applied after some type of deoxidation.

This result led the researchers to investigate the performance of trivalent chromium compositions as sealers for anodized AAs. Initial test runs using the thin-film sulfuric acid anodize process followed by immersion in the Trivalent Chromium Process (TCP) demonstration tank were successful in demonstrating that TCP solutions sealed the thin-film sulfuric acid anodize coating and resisted corrosion when exposed to ASTM B 117 neutral salt fog (NSF). Based on these promising results, a formal investigation of TCP as a sealer for anodized AAs was initiated.

The application of TCP as an anodized aluminum seal has been optimized and its corrosion performance was directly compared to other standard MIL-A-8625 sealing methods. MIL-A-8625 Type II (Sulfuric Acid Anodize, (SAA)), Type IIB (Thin-Film Sulfuric Acid Anodize, (TFSAA)), and Type IC (Boric Sulfuric Acid Anodize, (BSAA)) anodic coating types with either hot dilute chromate, hot water, or TCP seals were evaluated. Unsealed anodic coatings were also included in the evaluations. Application of TCP seal was optimized for corrosion performance and paint adhesion by varying the time and temperature of the TCP dwell, and evaluating subsequent corrosion and paint adhesion performance.

More recent assessments of TCP as an anodized sealer have been completed at Fleet Readiness Center (FRC) Southeast using the Metalast process. This process is compliant with MIL-A-8625 but yields much better control of coating quality, leading to better corrosion resistance. The Metalast anodizing process is described in detail in NAWCADPAX/TR-2007/154 “Improved Materials and Processes,” of 25 October 2007.

METHODS

COATING PREPARATION

Aluminum test panels were procured from Q-panel. Before anodizing, panels were immersion degreased or wiped with acetone, cleaned in Turco 4215 at 115-120ºF for 15 min, double rinsed in hot tap water, deoxidized in Turco Smut Go NC for 1-10 min, and double cold tap water rinsed. After this rinse, panels were immersed in selected anodizing solution and processed according to work instructions or local process specifications.

After anodizing, panels were rinsed in cold tap water and then immersed in hot water, dilute chromate, or TCP sealers. Processing variables for each sealer and deviations for the anodize processes are noted for each test matrix.

Panels requiring primer for painted corrosion and paint adhesion tests were prepared within 24 hr of sealing. Primers used were qualified to either MIL-PRF-23377 or MIL-PRF-85582 and are noted for each test set. After painting, panels were allowed to cure in the laboratory at ambient conditions for 14 days before testing.

CORROSION

Corrosion was evaluated by exposing panels to ASTM B 117 NSF or SO_2 salt fog. Painted panels were scribed through to substrate using a carbide tipped scribe tool, making a large X across surface of coating. Corrosion performance was evaluated in accordance ASTM D 1654 methods A and B, in which ratings range from 0 (fully corroded) to 10 (no corrosion or undercutting).

PAINT ADHESION

In most cases, paint adhesion testing was conducted in conjunction with the corrosion evaluations. The goal was to optimize TCP seal application for corrosion and paint adhesion performance, and compare its performance to dilute chromate seal. In each evaluation, painted test panels were anodized and sealed identically and at the same time as unpainted test panels.

Primer systems used in the evaluations included MIL-PRF-23377 Type I Class C and Class N, MIL-PRF-85582 Type I Class C1 and MIL-PRF-85582 Type II Class N. Paint adhesion performance was evaluated on both dry and water soaked test panels ("dry" and "wet" tape adhesion). For the wet tape adhesion test, panels were fully immersed in containers of deionized water, and respective test sets were held at ambient conditions for 24 hr, at 120°F for 4 days, and at 150°F for 7 days. Immediately after soaking, the wet tape adhesion test was conducted in accordance with ASTM D 3359 Test Method A and ASTM D 714. Per the test methods, panels were rated from 0 (worst) to 5 (best) for adhesion, as well as prevalence of blistering.

TEST RESULTS

The following data are a result of a series of assessments using TCP which developed over time as the merits of TCP as an anodize sealer were elucidated and the composition of TCP evolved.

TEST MATRIX 1-2, MARCH 2001

The corrosion performance of TCP was initially compared to other sealers and unsealed anodic coatings in Inorganic Coatings Team (ICT) Test Matrix 1-2 in March 2001. Anodic coatings included SAA, TFSAA, and BSAA; sealers included hot dilute chromate with 25-min dwell, hot water with 25-min dwell, and room temperature TCP with 20-min dwell. Coating systems were evaluated on AAs 2024 and 7075. Table 1 shows coating weights (CWs) for each alloy and anodize type.

Table 1: CWs for each Alloy and Anodize Type Assessed in Matrix 1-2

Type	Alloy	Average Coating Weight (mg/ft2)	# panels
IIB	2024	390	18
	7075	607	18
IC	2024	334	24
	7075	545	27
II	2024	963	19
	7075	1767	22

Figure 1 shows the relative corrosion performance of each coating system after 1,000 hr of salt spray exposure in accordance with ASTM B 117. In this evaluation, TCP exhibited performance as good as dilute chromate and was significantly better than the hot water seal for SAA, TFSAA, and BSAA for both alloys. All of the unsealed panels were heavily corroded by the end of the test, highlighting the requirement that unsealed panels receive subsequent primer application and should never be left unpainted. The TCP used in this evaluation was 100% concentration TCP-P, or 6.0 grams per liter of basic chromium sulfate basic and 8.0 grams per liter potassium hexafluorozirconate with pH adjusted manually to 3.8 to 4.0.

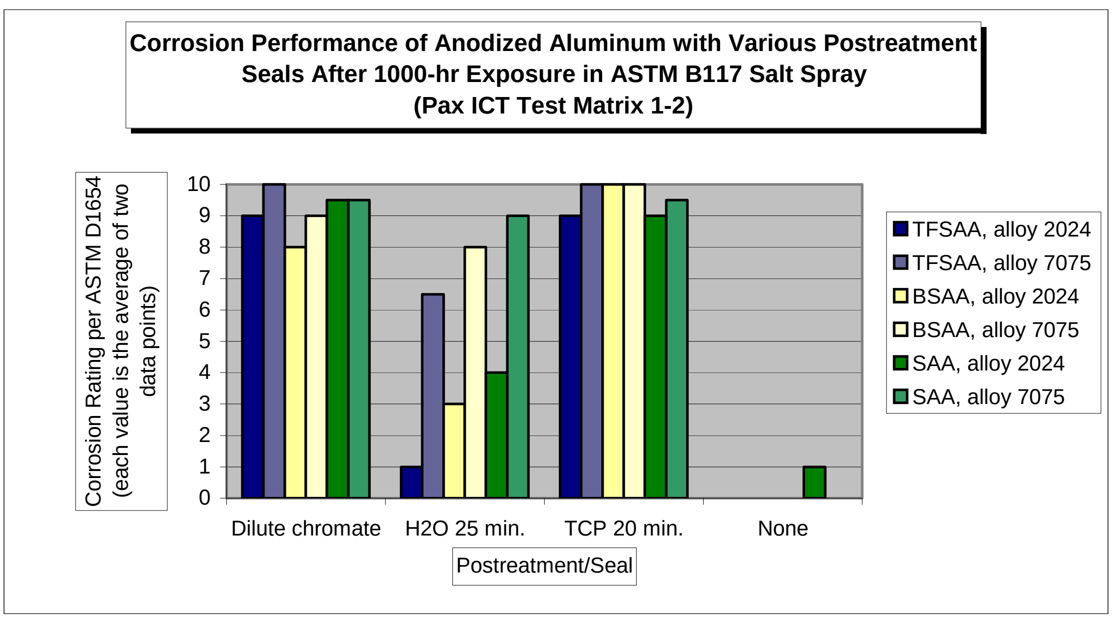


Figure 1: Corrosion Performance of Anodized Aluminum with Various Post-Treatment Seals after 1,000-hr Exposure in ASTM B 117 Salt Spray

Paint adhesion performance of Matrix 1-2 anodize and seal systems was also evaluated. Tables 2 and 3 show the relative adhesion performance of each anodic coating system paired with MIL-PRF-85582 Type I Class C1, MIL-PRF-85582 Type I Class N, and MIL-PRF-23377 Type I Class C1 primers. In this evaluation, paint adhesion performance of TCP sealed panels was not ideal regardless of AA or primer type. The surface of the test panels after sealing appeared slightly powdery. Based on these observations TCP dwell time was reduced in subsequent evaluations to reduce the generation of powdery surfaces and improve paint adhesion.

Table 2: Paint Adhesion Performance of Anodized Aluminum with Various Post-Treatments – AA 2024

Paint Adhesion Performance of Anodized Aluminum with Various Postreatments - alloy 2024

(Pax ICT Test Matrix 1-2)

TFSAA

Primer	MIL-PRF-85582 Type I Class C1				MIL-PRF-85582 Type II Class N				MIL-PRF-23377 Type I Class C			
Postreatment	dry	1-day wet	4-day wet	7-day wet	dry	1-day wet	4-day wet	7-day wet	dry	1-day wet	4-day wet	7-day wet
Dilute chromate	5	4	5	5	5	5	5	5	4	5	5	5
H2O 25 min.	5	4	5	3	5	5	5	5	3	4	5	4
TCP 20 min.	3	4	5	5	5	3	5	5	3	5	5	5
TCP 20 min. & H2O 25 min.	5	4	5	5	5	4	5	5	3	4	5	5
None	5	2	2	0	5	5	5	5	5	5	5	5

BSAA

Primer	MIL-PRF-85582 Type I Class C1				MIL-PRF-85582 Type II Class N				MIL-PRF-23377 Type I Class C			
Postreatment	dry	1-day wet	4-day wet	7-day wet	dry	1-day wet	4-day wet	7-day wet	dry	1-day wet	4-day wet	7-day wet
Dilute chromate	5	2	5	4	5	4	1	5	5	5	5	4
H2O 25 min.	5	4	5	5	5	4	5	4	4	4	5	4
TCP 20 min.	2	2	5	**5**	3	4	5	4	3	4	5	4
TCP 20 min. & H2O 25 min.	4	4	4	5	3	3	4	5	3	4	5	5
None	5	1	0	0	5	3	5	2	5	5	5	5

SAA

Primer	MIL-PRF-85582 Type I Class C1				MIL-PRF-85582 Type II Class N				MIL-PRF-23377 Type I Class C			
Postreatment	dry	1-day wet	4-day wet	7-day wet	dry	1-day wet	4-day wet	7-day wet	dry	1-day wet	4-day wet	7-day wet
Dilute chromate	5	4	3	3	5	5	5	5	5	5	5	5
H2O 25 min.	5	3	4	3	4	4	4	4	3	**4**	**5**	**4**
TCP 20 min.	4	**4**	**5**	**4**	5	4	5	**4**	3	5	5	3
TCP 20 min. & H2O 25 min.	3	3	3	**4**	4	3	3	**4**	3	4	5	5
None	5	2	2	1	5	5	5	5	3	4	5	5

Key

adhesion rating	0	1	2	3	4	5
blister rating	**dense**	**med dense**	**med**	**few**	**none**	

Table 3: Paint Adhesion Performance of Anodized Aluminum with Various Post-Treatments – AA 7075

Paint Adhesion Performance of Anodized Aluminum with Various Postreatments - alloy 7075
(Pax ICT Test Matrix 1-2)

TFSAA

Primer	MIL-PRF-85582 Type I Class C1				MIL-PRF-85582 Type II Class N				MIL-PRF-23377 Type I Class C			
Postreatment	dry	1-day wet	4-day wet	7-day wet	dry	1-day wet	4-day wet	7-day wet	dry	1-day wet	4-day wet	7-day wet
Dilute chromate	5	5	5	5	5	5	5	5	5	5	5	3
H2O 25 min.	5	4	5	4	5	5	5	5	5	5	5	4
TCP 20 min.	4	2	5	5	3	1	5	5	4	5	4	4
TCP 20 min. & H2O 25 min.	4	4	5	**5**	3	2	5	5	2	3	5	5
None	5	3	2	0	5	5	5	5	5	5	5	5

BSAA

Primer	MIL-PRF-85582 Type I Class C1				MIL-PRF-85582 Type II Class N				MIL-PRF-23377 Type I Class C			
Postreatment	dry	1-day wet	4-day wet	7-day wet	dry	1-day wet	4-day wet	7-day wet	dry	1-day wet	4-day wet	7-day wet
Dilute chromate	5	4	5	4	5	5	5	5	4	5	5	5
H2O 25 min.	5	3	5	4	5	4	5	4	5	5	5	5
TCP 20 min.	2	2	5	**5**	3	1	4	5	3	5	5	5
TCP 20 min. & H2O 25 min.	5	5	5	5	4	3	5	5	3	4	5	5
None	5	1	1	0	5	5	5	5	5	5	5	4

SAA

Primer	MIL-PRF-85582 Type I Class C1				MIL-PRF-85582 Type II Class N				MIL-PRF-23377 Type I Class C			
Postreatment	dry	1-day wet	4-day wet	7-day wet	dry	1-day wet	4-day wet	7-day wet	dry	1-day wet	4-day wet	7-day wet
Dilute chromate	5	3	5	3	5	5	3	5	5	5	5	4
H2O 25 min.	5	3	3	**1**	5	4	4	4	5	5	**4**	**4**
TCP 20 min.	4	4	**5**	**5**	3	0	5	**4**	3	4	5	4
TCP 20 min. & H2O 25 min.	5	5	5	5	5	3	4	4	2	5	4	4
None	5	3	4	2	5	5	5	5	4	5	5	5

Key

adhesion rating	0	1	2	3	4	5
blister rating	**dense**	**med dense**	**med**	**few**	**none**	

TEST MATRIX 2-1, OCTOBER 2001

In ICT Test Matrix 2-1, corrosion and paint adhesion performances were assessed by varying TCP dwell time. The goal was to establish processing parameters which would maximize the corrosion resistance and paint adhesion of a TCP-sealed anodic coating. TFSAA was the only anodic coating evaluated, and TCP dwell times were 2, 5, 10, and 20 min. TFSAA sealed with hot dilute chromate with a 25-min dwell was used as the control. The TCP used in this evaluation was 50% concentration TCP-S, or 3.0 grams per liter chromium sulfate basic, 4.0 grams per liter potassium hexafluorozirconate, and 0.12 grams per liter potassium tetrafluoroborate. Coating systems were evaluated on AAs 2024 and 7075. Table 4 shows CWs for each alloy.

Table 4: CWs for each Alloy Assessed in Matrix 2-1

Type	Alloy	Average Coating Weight (mg/ft2)	# panels
IIB	2024	452	12
	7075	725	11

Figure 2 shows the relative corrosion performance of each coating system after 1,000 hr of salt spray exposure in accordance with ASTM B 117. In this evaluation, TCP continued to perform well, and generally exhibited performance as good as dilute chromate for all dwell times for both alloys.

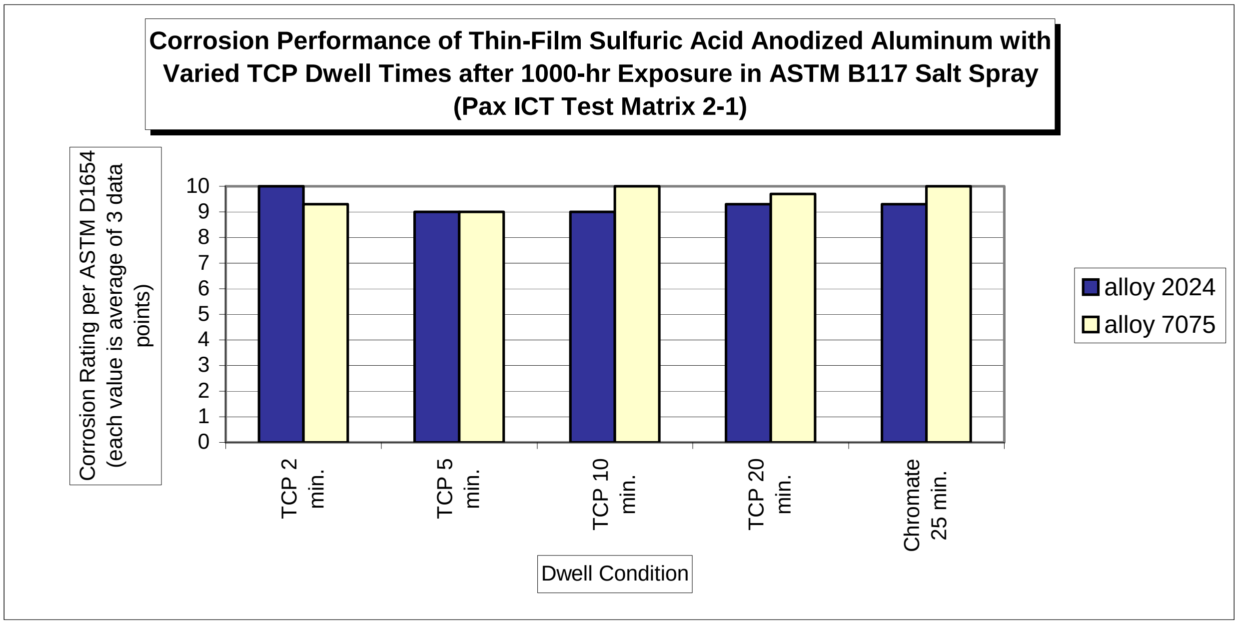


Figure 2: Corrosion Performance of TFSAA Aluminum with Varied TCP Dwell Times after 1,000-hr Exposure in ASTM B 117 Salt Spray

Paint adhesion performance of the TCP sealer applied at various dwell times with and without subsequent hot water sealer compared to dilute chromate was also evaluated in Matrix 2-1. Table 5 shows the adhesion performance of each sealer condition paired with chromated and nonchromated MIL-PRF-85582 primers which were selected due to their lower performance compared to the MIL-PRF-23377 primer in Matrix 1-2. TCP sealer applied using 2- to 10-min dwell provided excellent performance and was as good as dilute chromate adhesion performance for both paint systems. Corrosion and paint adhesion performance were optimum for the 10-min dwell condition.

Table 5: Paint Adhesion Performance of TFSAA Aluminum with Varied TCP Dwell Times

Paint Adhesion Performance of TFSAA Aluminum with Varied TCP Immersion Times
(ICT Test Matrix 2-1)

alloy 2024

Primer	MIL-PRF-85582 Type I Class C1				MIL-PRF-85582 Type II Class N			
Postreatment	dry	1-day wet	4-day wet	7-day wet	dry	1-day wet	4-day wet	7-day wet
TCP 2 min.	5	5	5	5	5	5	5	5
TCP 5 min.	5	5	5	5	5	5	5	5
TCP 10 min.	5	5	5	5	5	5	5	5
TCP 20 min.	4	4	5	5	3	3	5	5
TCP 2 min./Hot H2O 25 min.	4	0	3	3	5	5	4	4
TCP 5 min./Hot H2O 25 min.	5	5	5	5	5	5	5	5
TCP 10 min./Hot H2O 25 min.	5	4	5	5	5	5	5	5
TCP 20 min./Hot H2O 25 min.	5	5	5	5	5	5	5	5
Dilute chromate 25 min.	5	4	5	5	5	5	5	5

alloy 7075

Primer	MIL-PRF-85582 Type I Class C1				MIL-PRF-85582 Type II Class N			
Postreatment	dry	1-day wet	4-day wet	7-day wet	dry	1-day wet	4-day wet	7-day wet
TCP 2 min.	5	5	5	5	5	5	5	5
TCP 5 min.	5	5	5	5	5	5	5	5
TCP 10 min.	5	5	5	5	5	5	5	5
TCP 20 min.	5	5	5	5	5	5	5	5
TCP 2 min./Hot H2O 25 min.	5	0	3	3	5	5	5	5
TCP 5 min./Hot H2O 25 min.	5	5	5	5	5	5	5	5
TCP 10 min./Hot H2O 25 min.	5	5	5	5	5	5	5	5
TCP 20 min./Hot H2O 25 min.	5	5	5	5	5	5	4	5
Dilute chromate 25 min.	5	5	5	5	5	5	5	5

Key

adhesion rating	0	1	2	3	4	5
blister rating	**dense**	**med dense**	**med**	**few**	**none**	

TEST MATRIX 2-22, JULY 2002

In ICT Test Matrix 2-22, the corrosion performance of TCP with an additive intended to impart color change was evaluated for the first time. The TCP was applied to both TFSAA and SAA for 10 min at ambient temperature. The coating system was evaluated on AAs 2024 and 7075. The TCP formulation used in this evaluation was 50% concentration TCP-S plus the additive. The additive and its concentration cannot be documented due to intellectual property restrictions. Unlike its use as a conversion coating, the color of the TCP sealed anodize coating was the same with or without the additive. Table 6 shows CWs for each alloy and anodize type.

Table 6: CWs for each Alloy Assessed in Matrix 2-22

Type	Alloy	Average Coating Weight (mg/ft2)	# panels
IIB	2024	525	6
	7075	808	6
II	2024	2363	6
	7075	989	6

Figure 3 shows the relative corrosion performance of each coating system after 1,000 hr of salt spray exposure in accordance with ASTM B 117. In this evaluation, the TCP with additive provided similar corrosion protection compared to previously evaluated TCP without the additive. TCP performance was consistent compared to previous evaluations. Since the focus of this study was to assess the affect of the additive on TCP seal corrosion performance, paint adhesion tests were not conducted.

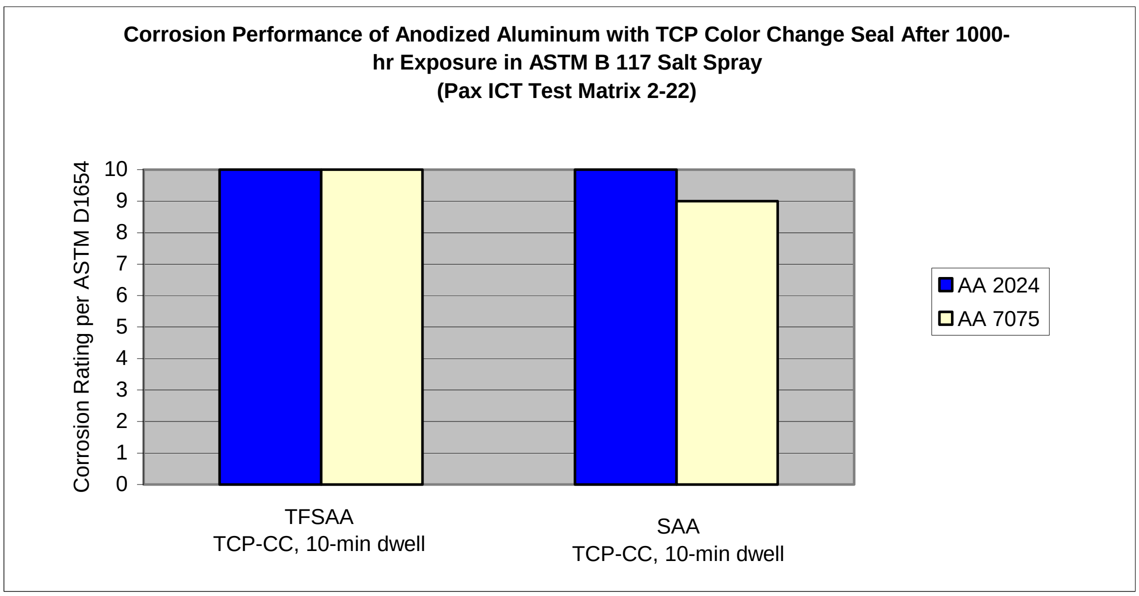


Figure 3: Corrosion Performance of Anodized Aluminum with TCP Color Change Seal after 1,000-hr Exposure in ASTM B 117 Salt Spray

TEST MATRIX 3-7, JANUARY 2003

In ICT Test Matrix 3-7, the corrosion performance of a variety of TCP formulations applied at a variety of dwell conditions on TFSAA was evaluated. A totally nonchromium sealer, NCP, was also evaluated for the first time. Coating systems were evaluated on AA 2024 only. Table 7 shows CWs for each alloy.

Table 7: CW Average for Matrix 3-7

Type	Alloy	Average Coating Weight (mg/ft2)	# panels
IIB	2024	532	3
	7075	825	3
II	2024	1928	3
	7075	924	3

Figure 4 shows the relative corrosion performance of each coating system after 1,008 hr of NSF. In this evaluation, TCP continued to exhibit consistent, good corrosion performance. There is no apparent gain in corrosion performance by increasing either the dwell time or temperature beyond the ambient 10-min condition. All of the TCP formulations performed similarly, and NCP exhibited a slight decrease in corrosion performance. The TCP formulations used in this evaluation were as follows: TCP5B3 is 50% concentration TCP-S, TCP5B3Z4 is 50% concentration TCP-S plus an additive intended to impart color change, TCP5P is 50% concentration TCP-P, and TCP5PZ2 is 50% concentration TCP-P plus an additive intended to impart color change.

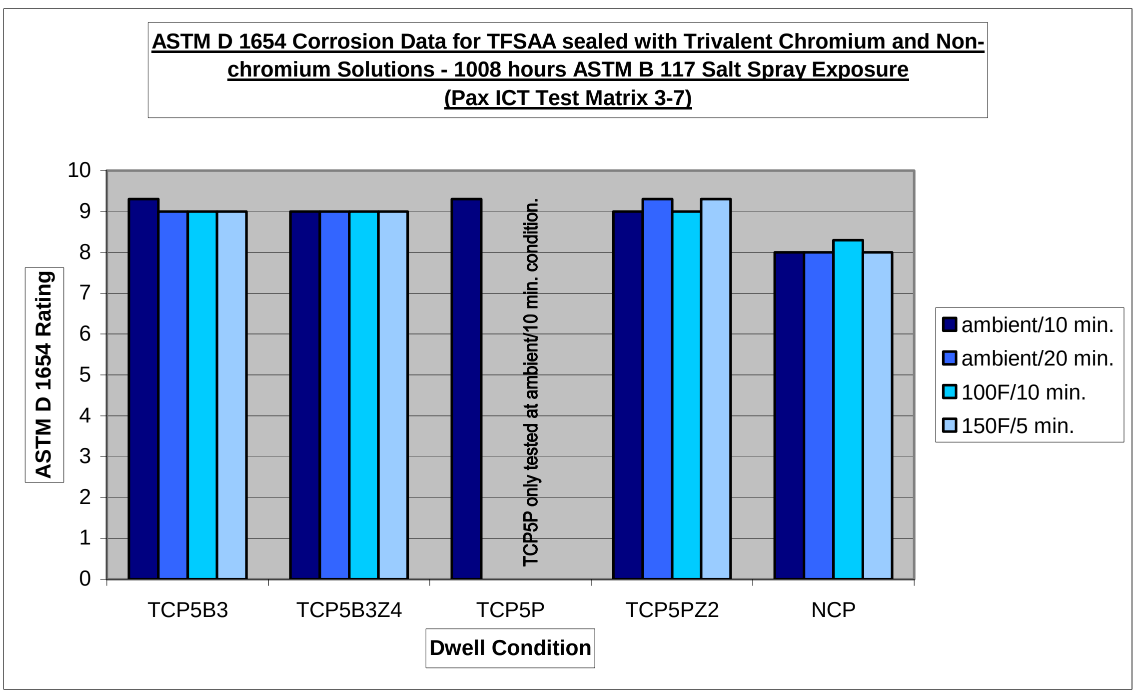


Figure 4: ASTM D 1654 Corrosion Data for TFSAA Sealed with Trivalent Chromium and Nonchromium Solutions after 1,000-hr ASTM B 117 Salt Spray Exposure

Table 8 shows the corresponding paint adhesion testing for Matrix 3-7. The ambient, 10-min dwell condition for TCP and NCP provided the best paint adhesion performance regardless of TCP and primer type. Increasing seal dwell time and temperature was detrimental to paint adhesion performance and did not increase corrosion performance.

Table 8: Paint Adhesion Performance of TFSAA on AA 2024 for TCP and NCP Seal

Paint Adhesion of TFSAA on AA2024 for TCP and NCP Seal (Pax ICT Test Matrix 3-7)						
Primer	MIL-PRF-85582 Type I Class C1		MIL-PRF-85582 Type II Class N		MIL-PRF-23377 Type I Class C	
Post-treatment	Dry	4-day wet	Dry	4-day wet	Dry	4-day wet
TCP5PZ2 ambient/10 min.	5	4	5	4	5	5
TCP5PZ2 ambient/20 min.	5	4	5	4	5	5
TCP5PZ2 100F/10 min.	5	4	5	4	5	5
TCP5PZ2 150F/5 min.	5	5	4	4	3	5
TCP5B3 100F/10 min.	5	4	5	4	4	5
TCP5B3 150F/5 min.	5	4	5	4	5	5
TCP5B3Z4 ambient/20 min.	5	5	4	4	5	5
TCP5B3Z4 100F/10 min.	3	4	4	4	3	5
TCP5B3Z4 150F/5 min.	3	4	3	4	3	5
NCP ambient/20 min.	5	3	5	4	5	5
NCP 100F/10 min.	5	3	5	4	5	5
NCP 150F/5 min.	5	3	5	4	5	5
Key						
adhesion rating	0	1	2	3	4	5
blister rating	**dense**	**med dense**	**med**	**few**	**none**	

TEST MATRIX 3-15, JULY 2003

In ICT Test Matrix 3-15, a follow-on evaluation of the corrosion performance of TCP with color change additive was conducted at longer NSF exposure. In this evaluation, the TCP with additive was applied at a variety of dwell conditions on TFSAA. NCP sealer was also evaluated again to verify and validate previous results. The TCP formulations used in this evaluation were 50% concentration TCP-P with an additive (TCP-cc1) and without an additive intended to impart color change. Coating systems were applied to AA 2024 only. Table 9 shows CW average for TFSAA on 2024-T3 aluminum.

Table 9: CW Average for TFSAA Assessed in Matrix 3-15

Type	Alloy	Average Coating Weight (mg/ft2)	# panels
IIB	2024	355	9

Figure 5 shows the relative corrosion performance of each coating system after 1,250 hr of salt spray exposure in accordance with ASTM B 117. In this evaluation, TCP, both with and without the color change additive, continued to provide good corrosion performance and was consistent with previous evaluations. Again, there is no apparent gain in corrosion performance by increasing either the dwell time or temperature beyond the ambient 10-min condition. NCP also performed consistently compared to previous evaluations, and exhibited a clear decrease in corrosion performance compared to TCP, but still much better than hot water sealing.

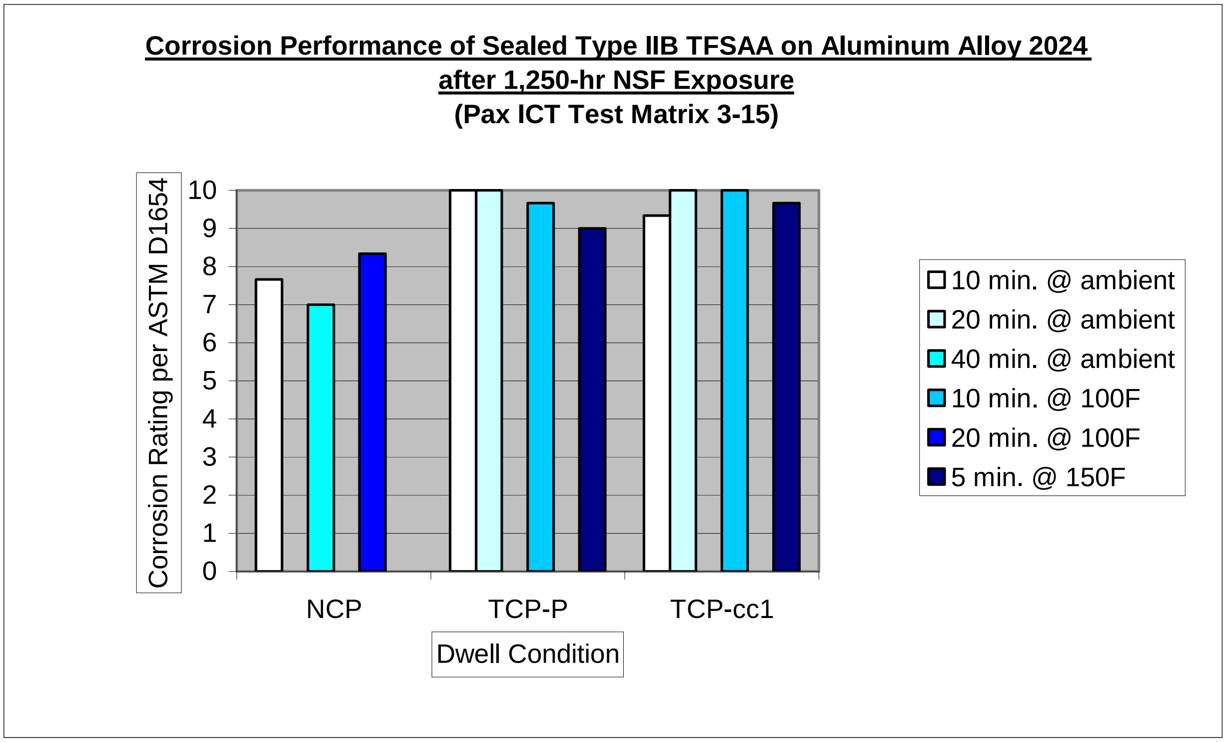


Figure 5: Corrosion Performance of Sealed Type IIB TFSAA on AA 2024
after 1,250-hr NSF Exposure

Table 10 shows the corresponding paint adhesion data for Matrix 3-15. In this evaluation, all seal application conditions generally provided excellent adhesion performance. The TCP 10-min ambient seal condition continued to perform well. Adhesion testing was not conducted for TCP-cc1 seal since it did not provide a benefit over TCP-P.

Table 10: Paint Adhesion Performance of TFSAA on AA 2024 with TCP-P or NCP Seal

Paint Adhesion on TFSAAand AA2024 with TCP-P and NCP Seal (Pax ICT Test Matrix 3-15)						
Primer	MIL-PRF-85582 Type I Class C1		MIL-PRF-85582 Type II Class N		MIL-PRF-23377 Type I Class C	
Post treatment	Dry	4-day wet	Dry	4-day wet	Dry	4-day wet
NCP, 10 min. @ ambient	5	5	5	5	4	5
NCP, 40 min. @ ambient	5	5	5	5	5	5
NCP, 20 min. @ 100F	5	5	5	5	5	5
TCP-P, 10 min. @ ambient	5	5	5	5	4	5
TCP-P, 20 min. @ ambient	5	5	5	5	5	5
TCP-P, 10 min. @ 100F	5	5	5	5	5	5
TCP-P, 5 min. @ 150F	5	5	5	5	3	5
Key						
Adhesion Rating ASTM D 3359	0	1	2	3	4	5
Blister Rating ASTM D 714	dense	med dense	med	few	none	

TEST MATRIX 4-15, AUGUST 2004

In ICT Test Matrix 4-15, an evaluation of the corrosion performance of TFSAA applied at various CWs with subsequent sealers was evaluated. The anodic CWs targeted were low, medium, and high, as shown in table 11, and within the allowable CW range of 200 to 1,000 mg/ft^2, as specified for MIL-A-8625, Type IIB coatings. Sealers included hot dilute chromate with a 25-min dwell and ambient TCP with a 10-min dwell. The TCP used in this evaluation was 50% concentration TCP-S. Unsealed panels were also evaluated. Coating systems were applied to AAs 2024, 7075, and 7050.

Table 11: TFSAA CWs for Alloys Processed in Matrix 4-15

Type	Alloy	Designation	Average Coating Weight (mg/ft2)
IIB	2024	Low Coating Weight (LCW)	258
		Medium Coating Weight (MCW)	563
		High Coating Weight (HCW)	710
	7075	Medium Coating Weight (MCW)	415
		High Coating Weight (HCW)	874
	7050	Medium Coating Weight (MCW)	314
		High Coating Weight (HCW)	699

Figures 6, 7, and 8 show the relative corrosion performance of each coating system after 1,000, 3,000, and 4,500 hr of salt spray exposure in accordance with ASTM B 117. In this evaluation, TCP provided similar corrosion protection compared to dilute chromate through 1,000-hr exposure. During long-term exposure up through 4,500 hr, the TCP seal significantly outperformed dilute chromate for all anodic CWs on all alloys. Almost all of the unsealed panels were fully corroded by 1,000 hr of exposure, emphasizing the need for subsequent primer application on unsealed components. Through 1,000 hr of exposure for sealed panels, the low anodic CW on alloy 2024 was the only condition that did not perform well, regardless of sealer. Based on this result, increasing the minimum CW specified in MIL-A-8625 for Type IIB coatings should be considered. Note that, in this evaluation, the minimum allowable Type IIB CW was achievable for the 2024 alloy only. With typical BSAA and TFSAA processing, it is difficult to form anodic coatings lower than about 400 mg/ft^2 on 7000-series AAs.

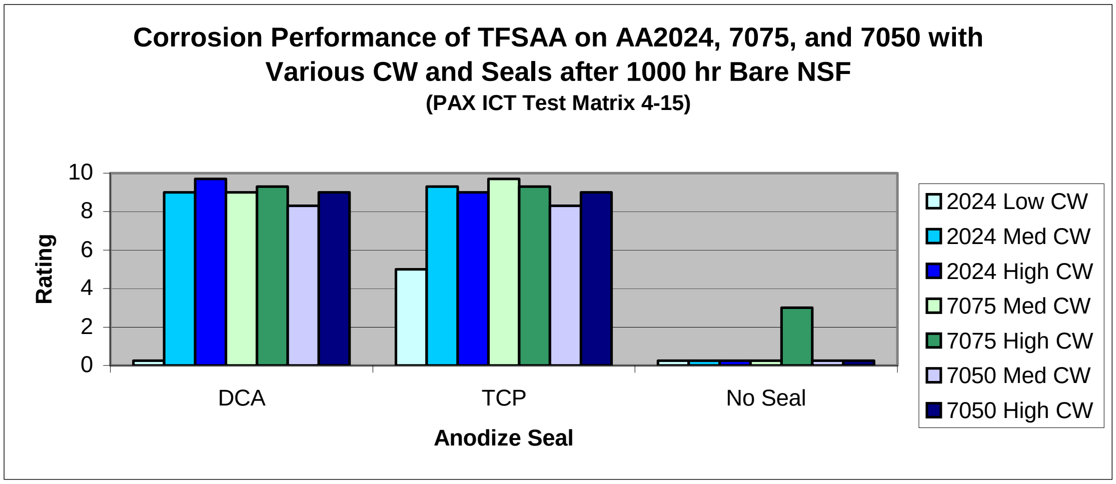


Figure 6: Corrosion Performance of TFSAA on AA 2024, 7075, and 7050 with Various CW and Seals after 1,000-hr Bare NSF

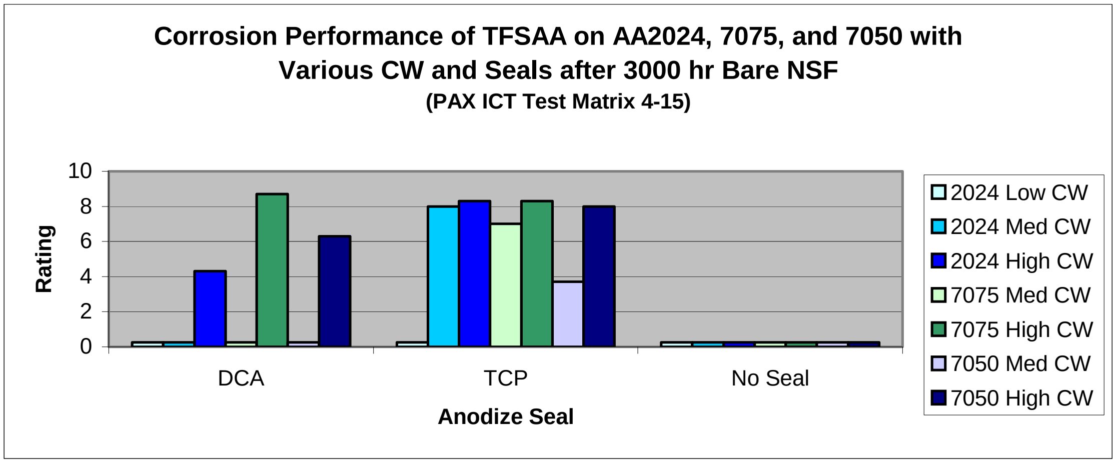


Figure 7: Corrosion Performance of TFSAA on AA 2024, 7075, and 7050 with Various CW and Seals after 3,000-hr Bare NSF

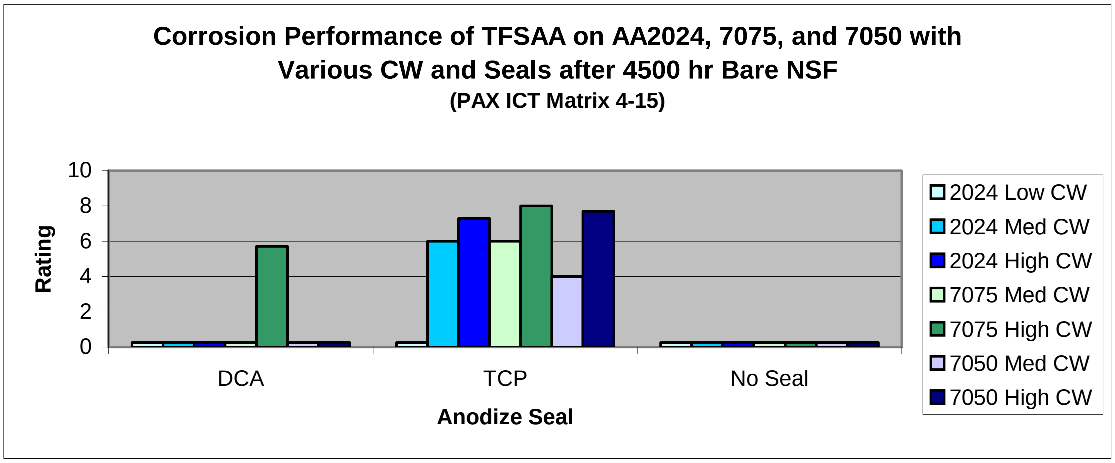


Figure 8: Corrosion Performance of TFSAA on AA 2024, 7075, and 7050 with Various CW and Seals after 4,500-hr Bare NSF

Tables 12, 13, and 14 show the corresponding paint adhesion data for Matrix 4-15. Paint adhesion performance was consistent with previous evaluations and generally very good for all anodic CW sets and alloys for MIL-PRF-23377 primer. The same is also generally true for the HCW sets for all alloys and all primer systems. Performance of TCP sealed and unsealed systems were generally degraded, however, for the LCW and MCW sets for both MIL-PRF-85582 primer systems when compared to dilute chromate seal. The same trend is also seen for dilute chromate seal although not as pronounced. The data support increasing the minimum allowable anodic CW for Type IIB anodic coatings in MIL-A-8625F.

For the medium and high anodic CW sets paired with MIL-PRF-85582 primer systems for the 7050 series alloy, an overall degradation in performance was seen for TCP seal compared to dilute chromate. This is inconsistent with previous evaluations and may indicate that MIL-PRF-85582 primer performance is generally less consistent than MIL-PRF-23377 primers, especially on unsealed and TCP sealed anodic coatings.

Table 12: Paint Adhesion Performance of TFSAA on AA 2024 Comparing Anodic CW and Seal Type

Paint Adhesion Performance of TFSAA on AA 2024 With Various Coating Weights and Seals (Pax ICT Test Matrix 4-15)						
Primer	MIL-PRF-85582 Type I Class C1		MIL-PRF-85582 Type II Class N		MIL-PRF-23377 Type I Class C	
Post treatment	Dry	4-day wet	Dry	4-day wet	Dry	4-day wet
DCA, Low CW	5	5	4	4	5	5
DCA, Med CW	5	5	4	5	5	5
DCA, High CW	5	5	5	5	5	5
TCP, Low CW	3	5	2	4	5	5
TCP, Med CW	5	5	5	5	5	5
TCP, High CW	5	5	5	5	5	5
None, Low CW	5	0	4	3	5	4
None, Med CW	5	4	5	5	5	5
None, High, CW	5	5	5	5	5	5
Key						
Adhesion Rating ASTM D 3359	0	1	2	3	4	5
Blister Rating ASTM D 714	dense	med dense	med	few	none	

Table 13: Paint Adhesion Performance of TFSAA on AA 7075 Comparing Anodic CW and Seal Type

Paint Adhesion Performance of TFSAA on AA 7075 With Various Coating Weights and Seals (Pax ICT Test Matrix 4-15)						
Primer	MIL-PRF-85582 Type I Class C1		MIL-PRF-85582 Type II Class N		MIL-PRF-23377 Type I Class C	
Post treatment	Dry	4-day wet	Dry	4-day wet	Dry	4-day wet
DCA, Med CW	5	5	5	4	5	5
DCA, High CW	5	5	5	5	5	5
TCP, Med CW	5	4	4	5	5	5
TCP, High CW	4	5	4	5	5	5
None, Med CW	5	3	4	4	5	5
None, High, CW	5	4	5	5	5	5
Key						
Adhesion Rating ASTM D 3359	0	1	2	3	4	5
Blister Rating ASTM D 714	dense	med dense	med	few	none	

Table 14: Paint Adhesion Performance of TFSAA on AA 7050 Comparing Anodic CW and Seal Type

Paint Adhesion Performance of TFSAA on AA 7050 With Various Coating Weights and Seals						
(Pax ICT Test Matrix 4-15)						
Primer	**MIL-PRF-85582 Type I Class C1**		**MIL-PRF-85582 Type II Class N**		**MIL-PRF-23377 Type I Class C**	
Post treatment	**Dry**	**4-day wet**	**Dry**	**4-day wet**	**Dry**	**4-day wet**
DCA, Med CW	5	4	5	5	5	5
DCA, High CW	5	5	5	5	5	5
TCP, Med CW	3	4	2	3	5	5
TCP, High CW	4	5	3	4	5	5
None, Med CW	4	0	4	2	5	5
None, High, CW	5	5	5	5	5	5
Key						
Adhesion Rating ASTM D 3359	0	1	2	3	4	5
Blister Rating ASTM D 714	**dense**	**med dense**	**med**	**few**	**none**	

TEST MATRIX 5-8, MARCH 2005

In ICT Test Matrix 5-8, an evaluation of the corrosion performance of TFSAA applied at various CWs with subsequent sealers and primers was performed. As shown in table 15, the anodic CWs achieved were low, medium, and high within the allowable CW range specified for MIL-A-8625, Type IIB coatings. Sealers included hot dilute chromate with a 25-min dwell and ambient TCP with a 10-min dwell. The TCP used in this evaluation was 50% concentration TCP-S. Primer systems included MIL-PRF-23377 Type I Class N, MIL-PRF-85582 Type 1 Class C1, and MIL-PRF-85582 Type I Class N. Bare and painted systems were evaluated. Painted systems were scribed prior to salt spray exposure and were rated per ASTM D 1654 after exposure. Coating systems were applied to AAs 2024, 7050, and 6061.

Table 15: TFSAA CWs for Alloys Processed in Matrix 5-8

Alloy	Test Coupon	Coating & Coupon weight (mg)	Coupon weight (mg)	Coating weight (mg/ft2)	Average Coating Weight (mg/ft2)	Batch Number	Batch Date
2024-T3 Low	1	21.5869	21.5333	257	257	1	31-May-05
	2	21.4908	21.4374	256			
	3	21.5605	21.5069	257			
2024-T3 Med	1	21.5456	21.4399	507	506	2	17-Jun-05
	2	21.4800	21.3759	500			
	3	21.5032	21.3970	510			
2024-T3 High	1	21.0476	20.9169	627	631	7	9-Jul-05
	2	21.5153	21.3864	619			
	3	20.8827	20.7479	647			
6061-T6 Med	1	20.5707	20.4683	492	495	3	28-Jun-05
	2	20.5664	20.4642	491			
	3	20.5642	20.4595	503			
6061-T6 High	1	20.6686	20.4801	905	917	4	30-Jun-05
	2	20.6935	20.501	924			
	3	20.6824	20.4904	922			
7050 Med	1	22.9654	22.8732	443	432	5	1-Jul-05
	2	22.3486	22.2568	441			
	3	23.1886	23.1026	413			
7050 High	1	23.5105	23.3775	639	635	6	1-Jul-05
	2	23.0368	22.9091	613			
	3	23.2879	23.1522	652			

Figures 9 and 10 show the relative corrosion performance of unpainted, sealed TFSAA after up to 1,300 hr of salt spray exposure in accordance with ASTM B 117 and 500 hr exposure in accordance with ASTM G 85 Annex 4. Consistent with previous evaluations, the low anodic CW condition provided significantly less corrosion protection compared to the MCW and HCW conditions. Generally, TCP seal performed as good as or better than dilute chromate seal in all coating and exposure conditions.

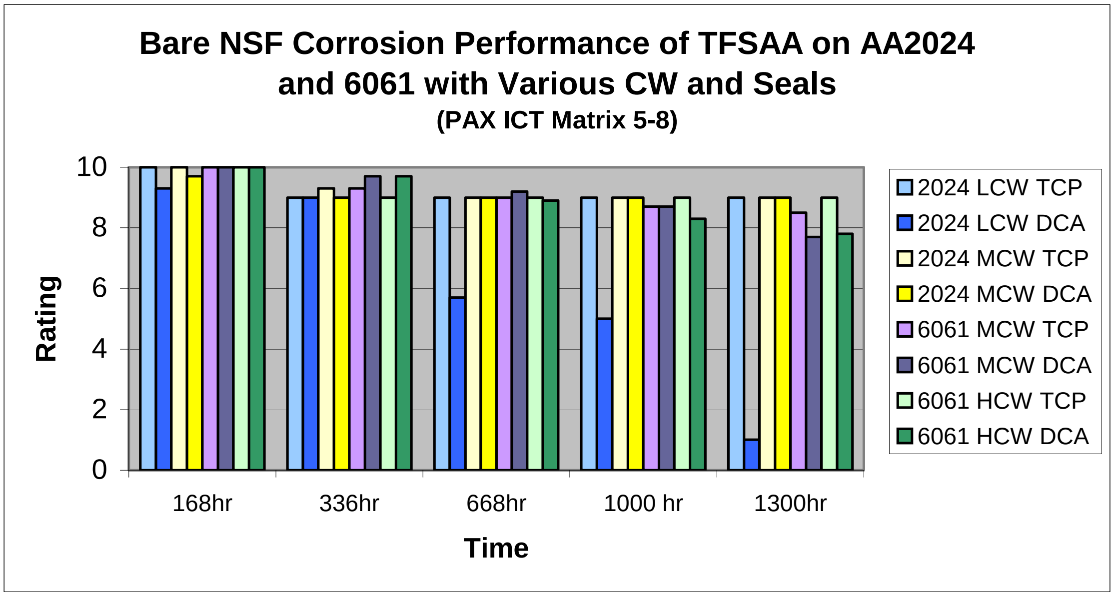


Figure 9: Bare (Unpainted) NSF Corrosion Performance of TFSAA on AA 2024 and 6061 with Various CW and Seals

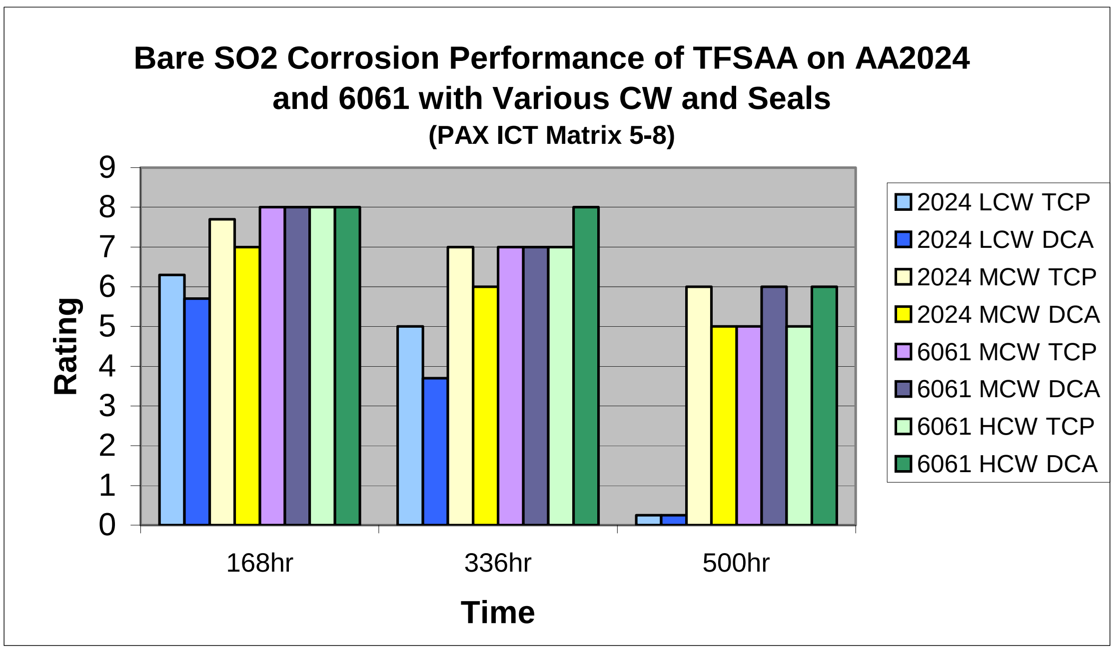


Figure 10: Bare (Unpainted) SO_2 Corrosion Performance of TFSAA on AA 2024 and 6061 with Various CW and Seals

Figures 11 and 12 show the relative corrosion performance of sealed and primed LCW TFSAA after up to 8,700 hr (1 year) of salt spray exposure in accordance with ASTM B 117 and 2,200 hr exposure in accordance with ASTM G 85 Annex 4. The control coating system in this evaluation was dilute chromate seal with subsequent MIL-PRF-85582 Type I Class C1 primer. For MIL-PRF-23377 Class N primer, the TCP seal generally performed as good as dilute chromate in NSF. A slight degradation in TCP performance compared to chromate was exhibited after SO_2 SF exposure. For MIL-PRF-85582 Class C1 primer, the TCP seal generally performed as good as dilute chromate in NSF. A slight improvement in TCP performance compared to chromate was exhibited after 2,200 hr of acidic salt spray exposure. For MIL-PRF-85582 Class N primer the TCP seal generally performed as good as dilute chromate over the duration of the tests. Overall, for LCW TFSAA, the TCP seal performed comparably to dilute chromate seal for primed coating systems.

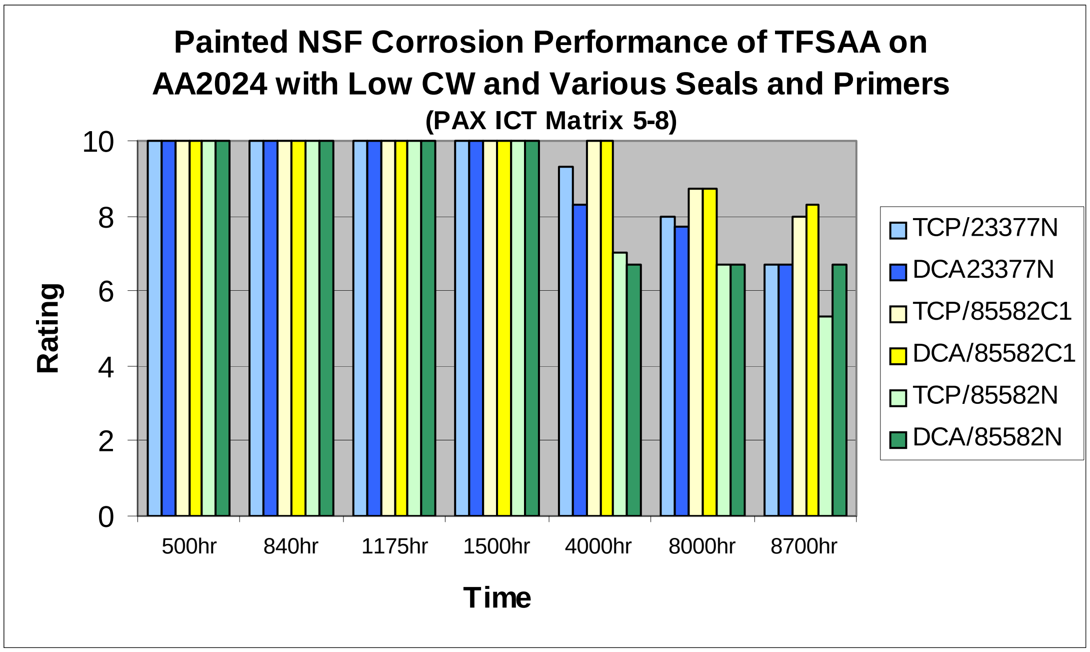


Figure 11: Painted NSF Corrosion Performance of TFSAA on AA 2024
with LCW and Various Seals and Primers

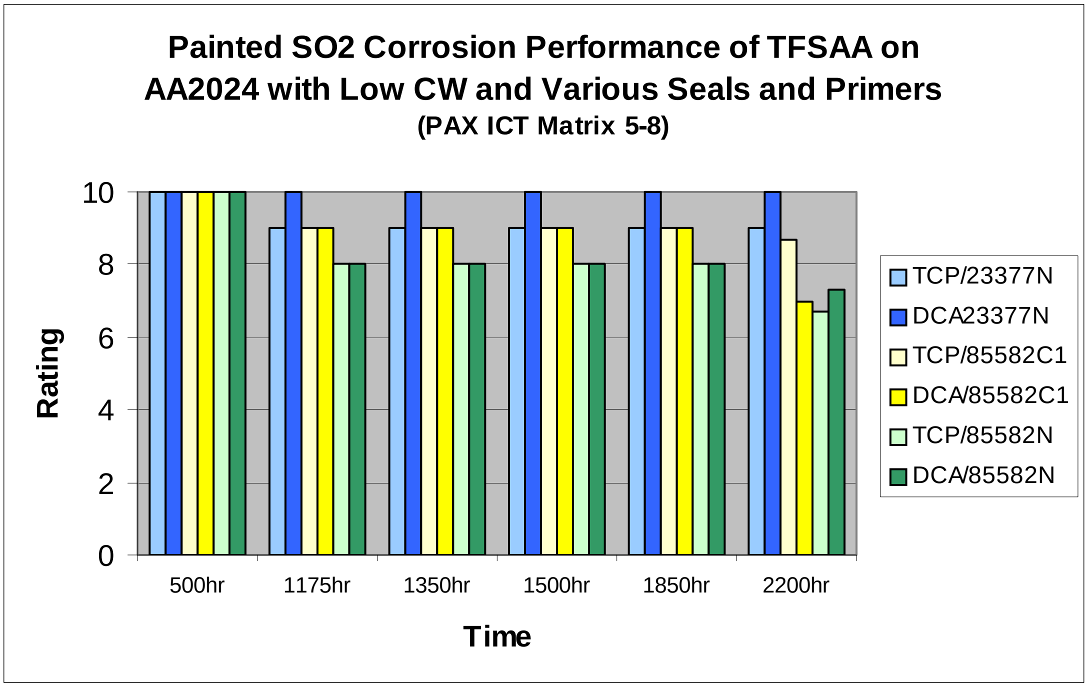


Figure 12: Painted SO_2 Corrosion Performance of TFSAA on AA 2024
with LCW and Various Seals and Primers

Figures 13, 14, and 15 show the relative corrosion performance of sealed and primed HCW and MCW TFSAA after up to 7,200 hr of salt spray exposure in accordance with ASTM B 117. The control coating system in this evaluation was dilute chromate seal with MIL-PRF-85582 Type I Class C1 primer. For all three alloys and primer systems, the TCP seal performed similarly to the dilute chromate seal. The MCW and HCW coatings also performed similarly regardless of sealer or primer.

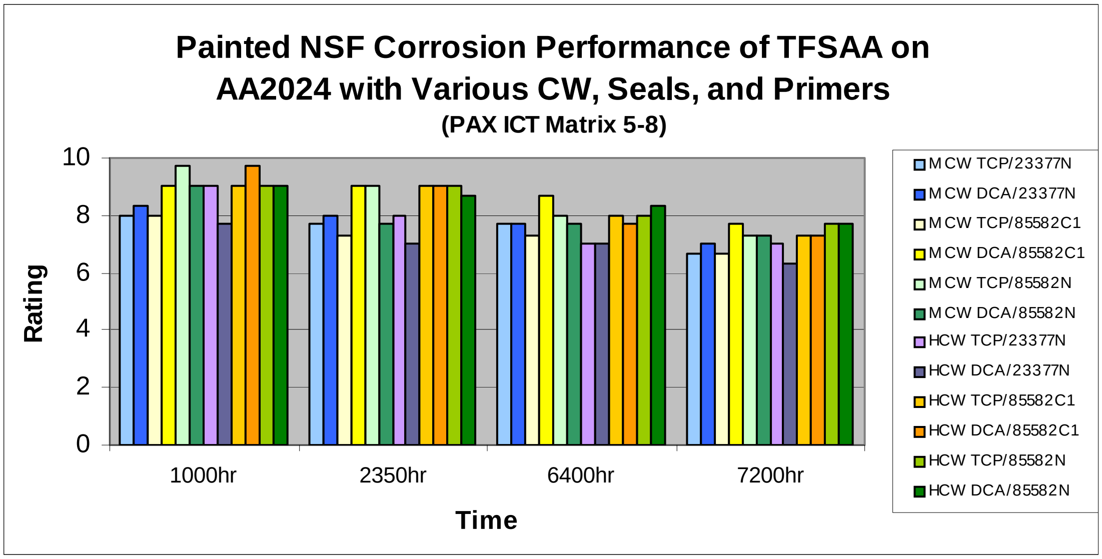


Figure 13: Painted NSF Corrosion Performance of TFSAA on AA 2024 with Various CW, Seals, and Primers

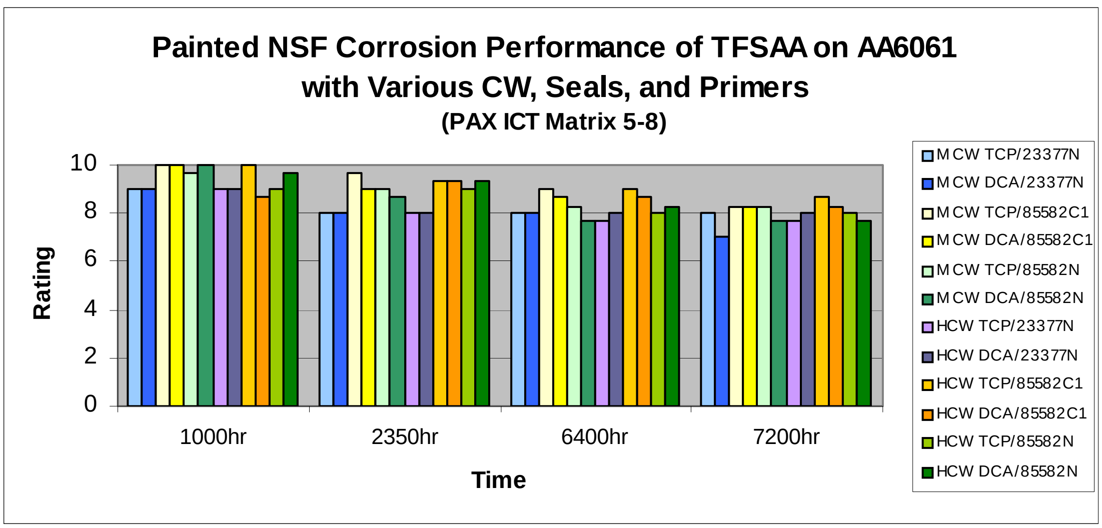


Figure 14: Painted NSF Corrosion Performance of TFSAA on AA 6061 with Various CW, Seals, and Primers

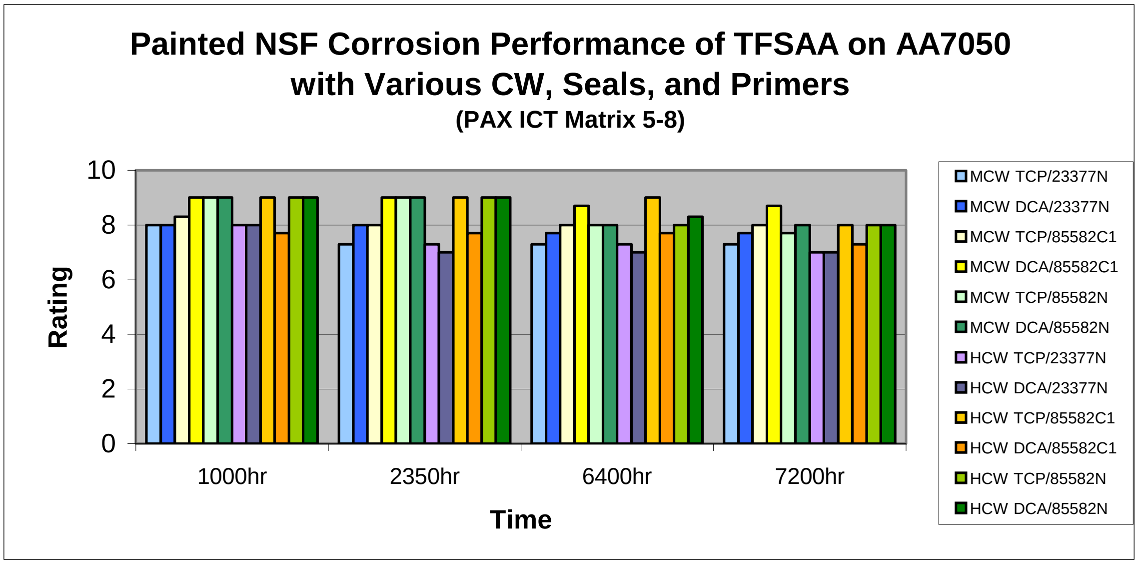


Figure 15: Painted NSF Corrosion Performance of TFSAA on AA 7050
with Various CW, Seals, and Primers

TEST MATRIX 7-1, OCTOBER 2006

In ICT Test Matrix 7-1, the corrosion performance of SAA, TFSAA, and hard anodize (MIL-A-8625 Type III) was evaluated. Coatings were applied at FRC Southeast (Jacksonville) using the Metalast process control system. The SAA and TFSAA were sealed with a 5% dichromate solution at 203ºF with a 15-min dwell or TCP at 80ºF with a 10-min dwell. Metalast TCP-HF at 50% concentration was used. The TCP-HF is a licensed, commercial version of TCP that is similar to TCP-S. The 5% dichromate seal is currently used at FRC Southeast on all sealed anodized parts. The hard anodize coatings were unsealed. The paint system used was MIL-PRF-85582 Type I Class C1 primer and MIL-PRF-85285 Class H Type I topcoat. Bare and painted systems were evaluated. Painted systems were scribed prior to salt spray exposure, and were rated per ASTM D 1654 at various exposure intervals. Coating systems were applied to AAs 2024 and 7075. Coating weight averages for TFSAA were 455 mg/ft^2 for 2024-T3 and 480 mg/ft^2 for 7075-T6. For SAA, CW averages were 3,259 mg/ft^2 for 7075-T6 and 2,898 mg/ft^2 for 2024-T3.

Figures 16, 17, and 18 show the performance of Metalast Type IIB and II anodic coatings on 2024-T3 with TCP or 5% chromate seal after 1,068, 1,571, 2,985, and 7,272 hr of NSF exposure. At 1,571 hr for the IIB coatings on 2024-T3, the TCP coating showed no sign of corrosion while the dichromate sealed coatings had failed completely. Both coatings showed no corrosion on 7075-T6. This performance is consistent with previous evaluations of Type IIB coatings using conventional anodize process. At 2,985 hr, TCP was still showing no signs of corrosion on either alloy. For the Type II coatings, at 1,571 hr, no coatings were showing any corrosion but the 5% dichromate sealed set was showing a reduction in the gold chromate color. This is typically a precursor to onset of visible corrosion. The TCP sealed coatings were essentially unchanged from 1,068 hr and showed no sign of corrosion.

At 7,272 hr, the TCP on Type II clearly outperformed the 5% dichromate seal on 2024-T3. For 7075-T6, the TCP had some discoloration that the dichromate panels did not show, but neither panel set showed signs of oxide-based corrosion products. Some of the difference between the alloys may be due to the CW differences. This performance was consistent with previous evaluations of Type II coatings using conventional anodizing.

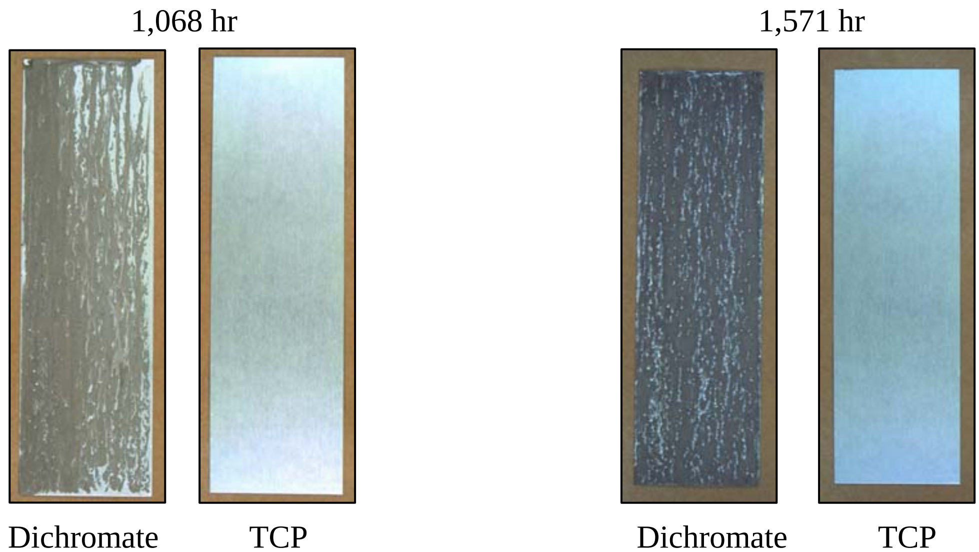
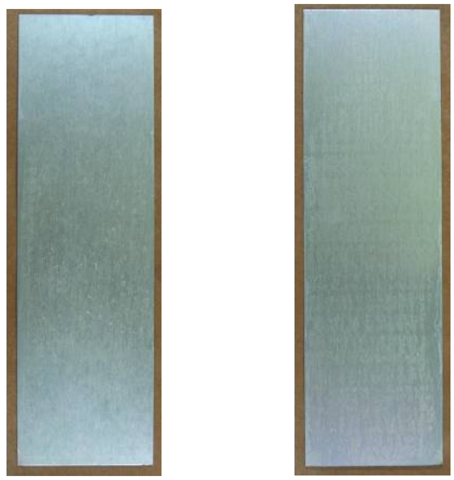


Figure 16: 5% Dichromate and TCP Sealed Metalast Type IIB Anodize Coatings on 2024-T3 Exposed to NSF

2,985 hr



2024-T3 7075-T6

Figure 17: TCP Sealed Metalast Type IIB Anodize Coatings Exposed to NSF for 2,985 hr

7,272 hr 7,272 hr

Dichromate TCP Dichromate TCP

7075-T6 2024-T3

Figure 18: 5% Dichromate and TCP Sealed Metalast Type II Anodize Coatings on 7075-T6 and 2024-T3 Exposed to NSF

Figures 19 and 20 detail the relative corrosion performance of the bare (unpainted) anodic coatings after up to 168 hr of SO_2 salt spray exposure in accordance with ASTM G 85 Annex 4. Consistent with previous long-term neutral salt spray exposure evaluation using conventional anodizing, the TCP seal performed significantly better than the 5% dichromate seal.

The unsealed hard anodize coating failed before 24 hr of exposure. Hard anodize coatings are typically left unsealed so that the characteristic wear surface is not softened. Preliminary assessments of TCP sealed Type II and IIB coatings has shown that TCP does not reduce wear characteristics, unlike hot water and dilute chromate seals. As a result, TCP has potential to seal Type III anodic coatings and increase corrosion resistance, while maintaining required wear properties. This application is currently being investigated by FRC Southeast.

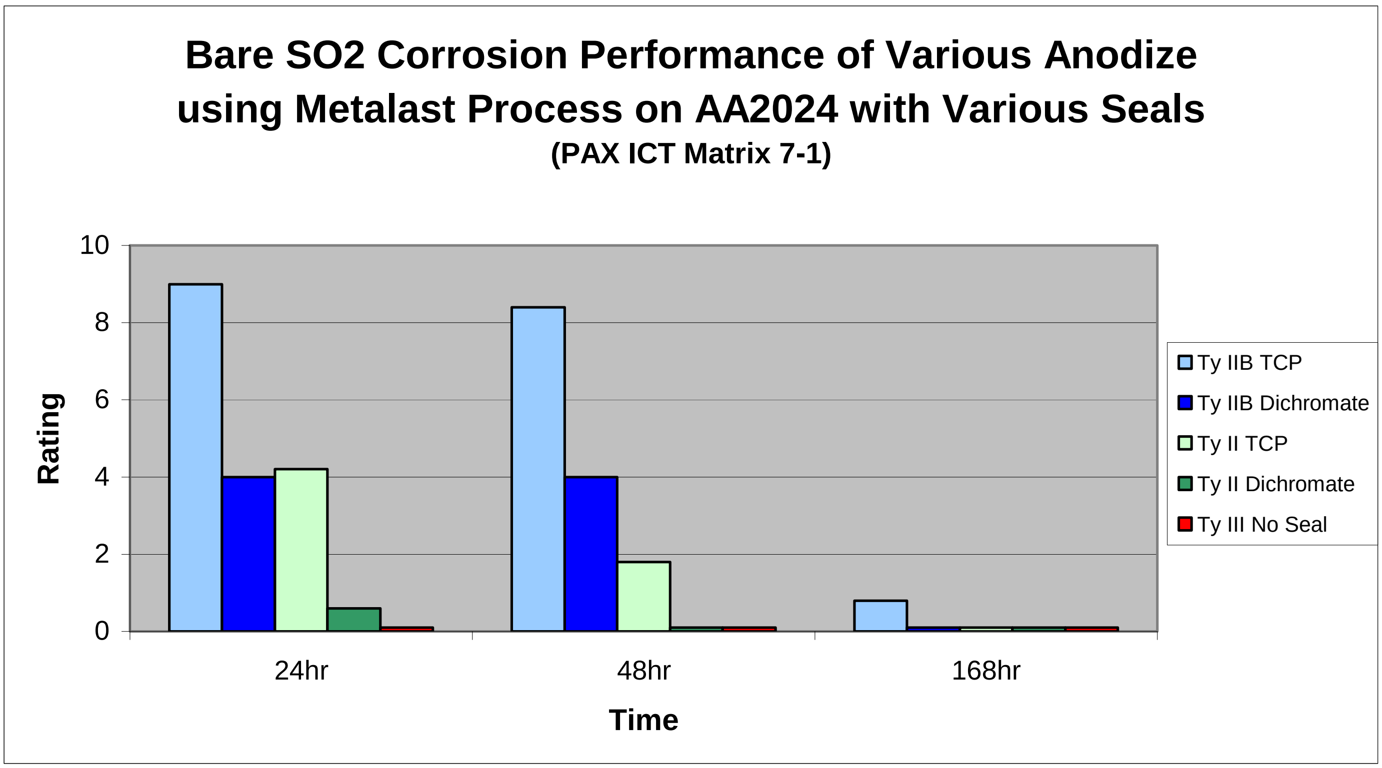


Figure 19: Bare SO_2 Corrosion Performance of Various Anodize using Metalast Process on AA 2024 with Various Seals

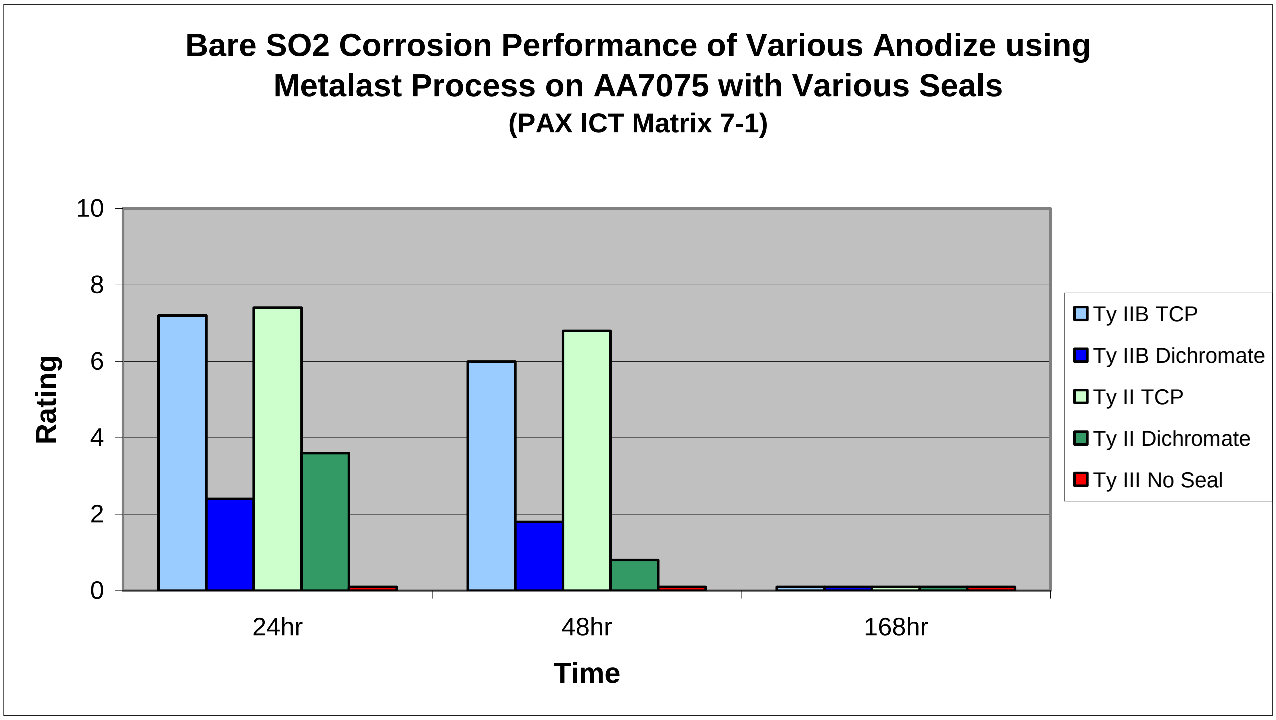


Figure 20: Bare SO_2 Corrosion Performance of Various Anodize using Metalast Process on AA 7075 with Various Seals

Figures 21 and 22 show the corrosion performance of the painted and scribed anodic coatings after 3,000 hr of SO_2 SF. The TCP seal performed similarly to the 5% dichromate seal for both SAA and TFSAA.

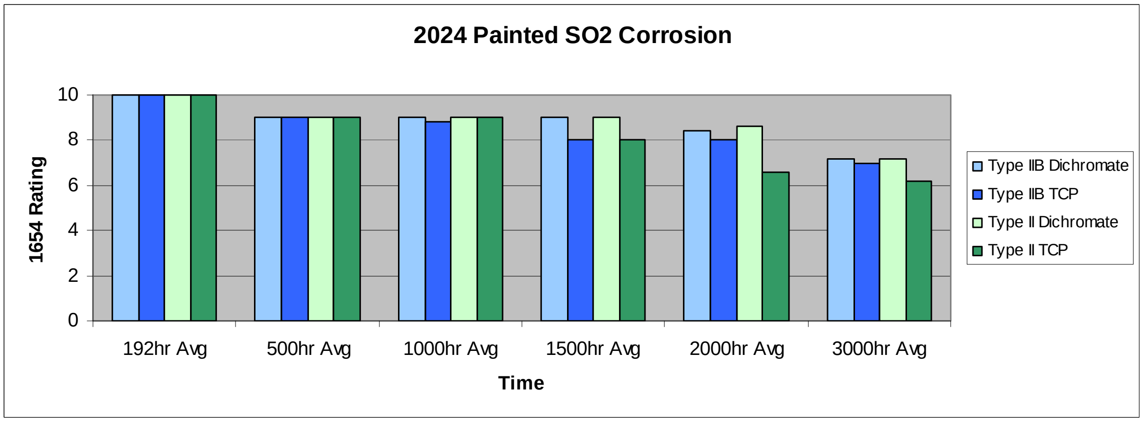


Figure 21: Painted and Scribed SO_2 Corrosion Performance of Various Anodize using Metalast Process on 2024-T3 with Various Seals

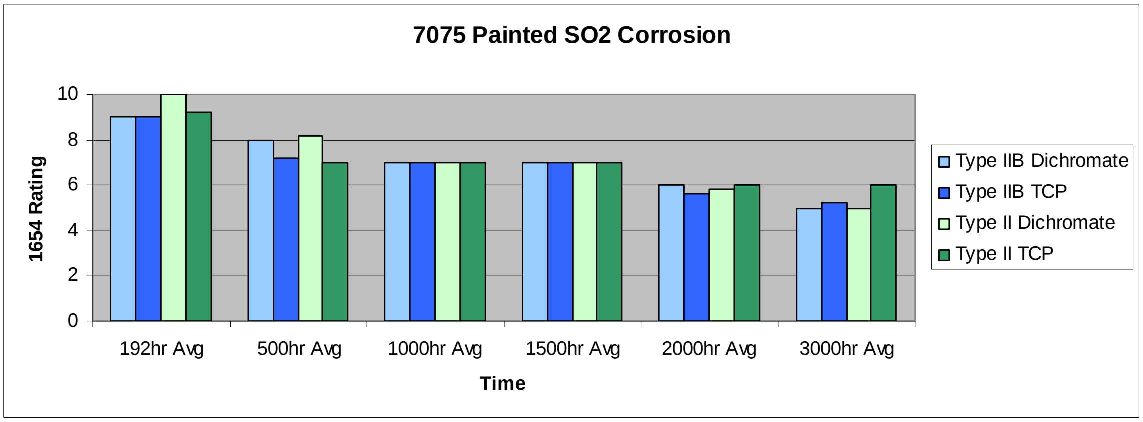


Figure 22: Painted and Scribed SO_2 Corrosion Performance of Various Anodize using Metalast Process on 7075-T6 with Various Seals

Figures 23 and 24 show the corrosion performance of the painted and scribed anodic coatings after 7,272 hr of NSF. The TCP seal performed similarly to the chromate seal for TFSAA on both alloys. For Type II coatings, the chromate sealed panels performed better on both alloys, showing less corrosion in scribes and less undercutting.

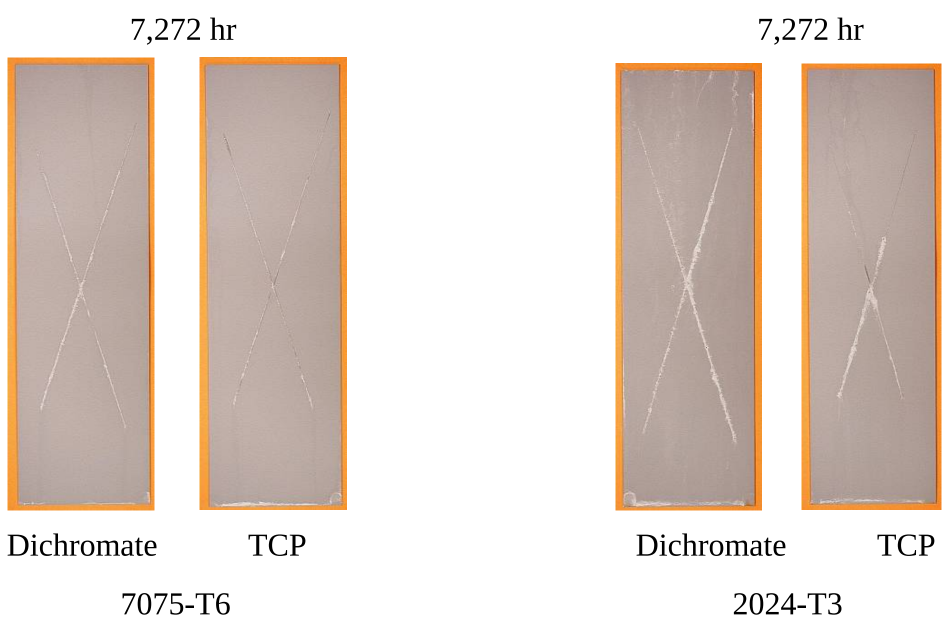


Figure 23: 5% Dichromate and TCP Sealed Metalast Type IIB (TFSAA) Anodize Coatings on 7075-T6 and 2024-T3 Exposed to NSF

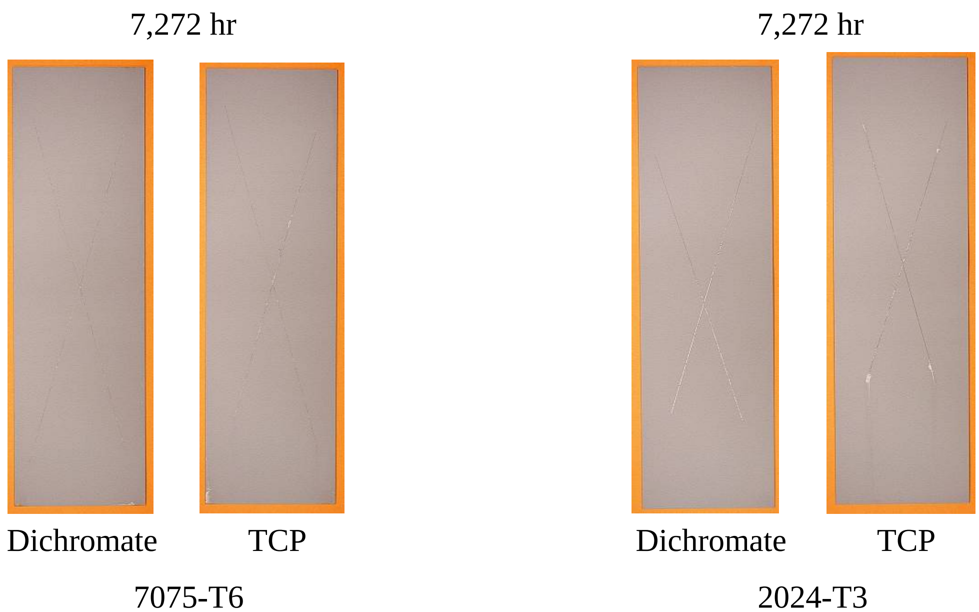


Figure 24: 5% Dichromate and TCP Sealed Metalast Type II (SAA) Anodize Coatings on 7075-T6 and 2024-T3 Exposed to NSF

Paint adhesion evaluations are shown in tables 16 and 17. Ratings of 4 or 5 are acceptable. As shown, all ratings are acceptable except for TCP on Type IIB 7075-T6 in the 4- and 7-day test. Additional testing will be done using shorter immersion times for TCP. Previous work on conventional anodize showed that adhesion is improved by shortening immersion time in TCP without compromising corrosion resistance.

Table 16: Paint Adhesion for Various Anodize using Metalast Process on 2024-T3 with Various Seals

MIL-A-8625	Seal	*Thickness (No Seal)	Coating Weight (No Seal)	†Dry Adhesion	†24 Hr Wet Adhesion	†4 Day Wet Adhesion	†7 Day Wet Adhesion
		Witness	*Witness*	*A*	*A*	*I*	*J*
TY IIB	Dichromate		458.9	5	5	5	5
	Dichromate		459.0	5	5	5	5
8ASF-13min	Dichromate		459.9				
	Dichromate		(459.3 mg/ft²)				
	Dichromate	0.1 ± 0.03 mils					
	TCP	(2.5 µm)	447.9	4	4	4	5
	TCP		454.6	5	5	4	5
	TCP		447.9				
	TCP		(450.1 mg/ft²)				
	TCP						
TY II	Dichromate		2,756.7	5	5	5	5
	Dichromate		2,979.5	5	5	5	5
12ASF-40min	Dichromate		2,903.9				
	Dichromate		(2,880.0 mg/ft²)				
	Dichromate	0.5 ± 0.03 mils					
	TCP	(12.7 µm)	3,007.7	5	5	5	5
	TCP		2,941.9	5	5	5	5
	TCP		2,798.8				
	TCP		(2,916.1 mg/ft²)				
	TCP						

Table 17: Paint Adhesion for Various Anodize using Metalast Process on 7075-T6 with Various Seals

MIL-A-8625	Seal	Thickness (No Seal)	Coating Weight (No Seal)	*Dry Adhesion	†24 Hr Wet Adhesion	†4 Day Wet Adhesion	†7 Day Wet Adhesion
		Witness	*Witness*	*A*	*A*	*I*	*J*
TY IIB	Dichromate		478.2	5	5	5	5
	Dichromate		479.6	5	5	5	5
8ASF-10min	Dichromate		483.9				
	Dichromate		(480.6 mg/ft²)				
	Dichromate	0.1 ± 0.03 mils					
	TCP	(2.5 µm)	484.9	4	4	3	3
	TCP		481	4	4	3	3
	TCP		474.3				
	TCP		(480.1 mg/ft²)				
	TCP						
TY II	Dichromate		2,919.8	5	5	5	5
	Dichromate		3,357.7	5	5	5	5
12ASF-35min	Dichromate		3,457.5				
	Dichromate		(3,245.0 mg/ft²)				
	Dichromate	0.5 ± 0.03 mils					
	TCP	(12.7 µm)	3,538.6	5	5	5	5
	TCP		3,167.5	5	5	5	5
	TCP		3,111.4				
	TCP		(3,272.5 mg/ft²)				
	TCP						

SUMMARY OF TESTING

Table 18 summarizes the testing which has been completed and documented in this report, including AAs, anodize processes, coatings, tests, and purpose.

Table 18: Summary of TCP Testing as Aluminum Anodize Sealer

Assessment	Alloys	Anodize process (MIL-A-8625)	Sealers	Coatings	Tests	Purpose
Matrix 1-2 (March 2001)	2024-T3, 7075-T6	II, IIB, IC	dilute chromate, water, TCP-P, none	MIL-PRF-85582 Type 1 Class C1, MIL-PRF-85582 Type 2 Class N, MIL-PRF-23377 Type 1 Class C	ASTM B 117 (1000 hrs), Dry and wet tape adhesion (1, 4, 7-day)	Initial evaluation of TCP as sealer
Matrix 2-1 (October 2001)	2024-T3, 7075-T6	IIB	dilute chromate, TCP-S	none	ASTM B 117 (1000 hrs), Dry and wet tape adhesion (1, 4, 7-day)	Optimize immersion time for TCP-S
Matrix 2-22 (July 2002)	2024-T3, 7075-T6	II, IIB	TCP-S, TCP-S with additives	none	ASTM B 117 (1000 hrs)	Evaluate zinc sulfate additives
Matrix 3-7 (January 2003)	2024-T3	IIB	TCP-P, TCP-S, TCP-P with zinc sulfate, TCP-S with zinc sulfate	MIL-PRF-85582 Type I Class C1 and Type II Class N, MIL-PRF-23377 Type I Class C	ASTM B 117 (1000 hrs), Dry and wet tape adhesion (4-day)	Evaluate different versions of TCP and NCP for first time. First evaluation of elevated sealer temperatures for TCP
Matrix 3-15 (July 2003)	2024-T3	IIB	NCP and TCP variants	none	ASTM B 117 (1250 hrs)	Follow-on testing to Matrix 3-7 with longer test exposure and longer immersion times in TCP
Matrix 4-15 (August 2004)	2024-T3, 7075-T6, 7050	IIB	none, dilute chromate, TCP-S	MIL-PRF-85582 Type I Class C1 and Type II Class N, MIL-PRF-23377 Type I Class C	ASTM B 117 (4500 hrs), Dry and wet tape adhesion (4-day)	Evaluate impact of various coating weights on corrosion and paint adhesion. Extend corrosion test to 4500 hours.
Matrix 5-8 (March 2005)	2024-T3, 7050, 6061-T6	IIB	dilute chromate, TCP-S	MIL-PRF-85582 Type I Class C1 and Type I Class N, MIL-PRF-23377 Type I Class C1 and Type I Class N	ASTM B 117 (1300 hrs- unpainted, 8700 hrs- painted), ASTM G 85 Annex 4 (500 hrs- unpainted, 2200 hrs painted)	First evaluation of MIL-PRF-23377 Class N with TCP. First evaluation using 6061 alloy. First evaluation using SO_2 salt fog on bare and painted panels
Matrix 7-1 (October 2006)	2024-T3, 7075-T6	Metalast II, IIB, III	Metalast TCP-HF at 50%	MIL-PRF-85582 Type 1 Class C1 and MIL-PRF-85285 Class H Type 1	ASTM B 117 (4000 hrs- unpainted, 7272 hrs- painted), ASTM G 85 Annex 4 (168 hrs- unpainted, 3000 hrs painted), Wet tape adhesion (1, 4, 7-day)	Evaluate performance of TCP using depot process line

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CONCLUSIONS

TCP has been evaluated as a sealer for MIL-A-8625 anodize Types IC, IIB, and II using a variety of common AAs. Testing has included developmental batches of TCP as well as commercial versions and coatings have been applied from pilot lines and depot process tanks. The following conclusions are evident from the data presented here:

- A single TCP solution can be used to seal MIL-A-8625 Type IC, IIB, and II anodic coatings at ambient conditions (typically 70-80°F).

- TCP sealer is effective at protecting all AAs from corrosion, in many cases performing better than the dilute chromate or 5% dichromate seals. This benefit is larger when coatings are assessed unpainted.

- Proper paint adhesion to TCP seal can be achieved for all anodize types but may require process optimization to find balance between acceptable adhesion and maximum corrosion performance.

- The lower CW range (200 to 400 mg/ft^2) in MIL-A-8625 for Type IC and IIB coatings provides inferior corrosion performance compared to middle and high range (400 to 1,000 mg/ft^2).

- There are large differences in corrosion performance between hot water sealed and TCP or chromate sealed coatings. This performance difference is not accounted for in MIL-A-8625F.

RECOMMENDATIONS

Authorize NAVAIR use of TCP as sealer for MIL-A-8625 Type IC, IIB and II anodic coatings for painted and unpainted applications.

Raise the minimum allowable CW in MIL-A-8625 from 200 mg/ft^2 to 400 mg/ft^2.

Create sealer class in MIL-A-8625 which sets requirements for corrosion resistance based on the two or three levels of performance when tested unpainted or “bare” in ASTM B 117 NSF. For example:

- Class 1: No corrosion after 336 hr
- Class 2: No corrosion after 672 hr

Continue assessing potential for TCP in sealing Type III anodize.

REFERENCES

1. NAWCAD Patuxent River Technical Report No. NAWCADPAX/TR-2005/189, Laboratory and Field Demonstration and Validation of Trivalent Chromium Pretreatment, of 28 Oct 2005.

2. Nonchromate Aluminum Pretreatments, Phase I Report, Environmental Security Technology Certification Program Project No. PP0025, of Aug 2003.

3. Nonchromate Aluminum Pretreatments, Phase II Interim Report, Environmental Security Technology Certification Program Project No. PP0025, of Sep 2004.

ABBREVIATIONS

AA	Aluminum Alloy
ASTM	American Society for Testing and Materials
BSAA	Boric-Sulfuric Acid Anodize
CW	Coating Weight
FRC	Fleet Readiness Center
HCW	High Coating Weight
ICT	Inorganic Coatings Team
LCW	Low Coating Weight
MCW	Medium Coating Weight
MIL-PRF	Military Performance Specification
NAS	Naval Air Station
NAVAIR	Naval Air Systems Command
NAWCAD	Naval Air Warfare Center Aircraft Division
NCP	Nonchromium Composition for Aluminum Pretreatment and Anodic Coating Sealing
NSF	Neutral Salt Fog
SAA	Sulfuric Acid Anodize
SO_2 SF	Sulfur Dioxide Salt Fog
TCP	Trivalent Chromium Compositions for Aluminum Pretreatment and Anodic Coating Sealing
TCP-P	Original TCP, Stabilized by pH Manipulation
TCP-S	TCP, Stabilized by Addition of Fluoride Compound
TCP-CC1	TCP-P with Additive for Color Change
TFSAA	Thin-Film Sulfuric Acid Anodize

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